



System Test: Superconducting Module & Test Facility and views from DESY and KEK

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Goal: Develop U.S. Capabilities in high gradient and high Q superconducting accelerating structure in support of the International Linear Collider and other accelerator projects of interest to U.S.



SMTF: Participating Institutions

- Argonne National Laboratory (ANL)
- Brookhaven National Laboratory (BNL)
- Cornell University
- Fermilab
- Jefferson Laboratory (JLAB)
- Lawrence Berkeley National Laboratory (LBNL)
- Los Alamos National Laboratory (LANL)
- MIT-Bates Laboratory
- National Superconducting Cyclotron Laboratory (MSU)
- Oak Ridge National Laboratory/(SNS)
- Stanford Linear Accelerator Center (SLAC)
- Expressed Interest: DESY, INFN, KEK, Korea, UK,....



Superconducting Module Test Facility

- A consortium of US laboratories and universities are proposing to construct a Superconducting RF Module & Test Facility (SMTF).
- The facility would fill in the gaps in the existing SCRF infrastructure present at the US laboratories.
- It will help facilitate state-of-the-art developments in high gradient and high Q SCRF cavities.
- While SMTF is primarily the Superconducting Cryomodule Test Facility. It is natural that the collaboration with specific interest (ILC-America, Proton Drive, CW, RIA...) will develop cryomodules using the US industries and infrastructure at US laboratories with their project goals.



Specific Goals for ILC: SMTF

- Demonstration of superconducting cavities with > 35 MV/m accelerating gradients operating at 1.3 GHz, in pulsed operation with a 1% duty factor and with high beam loading.
- Development of U.S. industrial capability for the fabrication of high performance SCRF cavities and associated infrastructures.
- Accelerate beam to ~ 1 GeV utilizing high performance accelerating cavities (> 35 MV/m, $Q > 1e10$).
 - An electron beam source (ILC quality beam) and accompanying diagnostics



What is an ILC RF Unit ?

- An RF unit will eventually need to be defined for both the 500 GeV and 1 TeV ILC designs.
- In our discussions, we are moving towards an ILC with 35 MV/m, 1.3 GHz cavities for both 500 GeV and 1 TeV operation.
- The power sources currently being developed can provide 10 MW of rf power so it is natural to define an rf unit as the number of cavities powered by such a source (i.e., one modulator and one klystron).
- Given the state of cryomodule development and the desire to have some overhead in choosing the ILC beam current, we define an RF unit for test purposes as two cryomodules with eight TESLA-like (9 cell) cavities each.
- Assuming 6% transport losses, each cavity in the rf unit could be powered up to 530 kW with a 10% overhead. At 35 MV/m, a 15 mA beam could be accelerated, which is about 15% more current than in the TESLA 800 design.
- The present design of the ILC cryostat is based on the Tesla design, which contains eight nine-cell cavities. It may be cost effective (needs study) for the ILC to have 12 nine-cell cavities per cryomodule.



Phases of ILC: SMTF

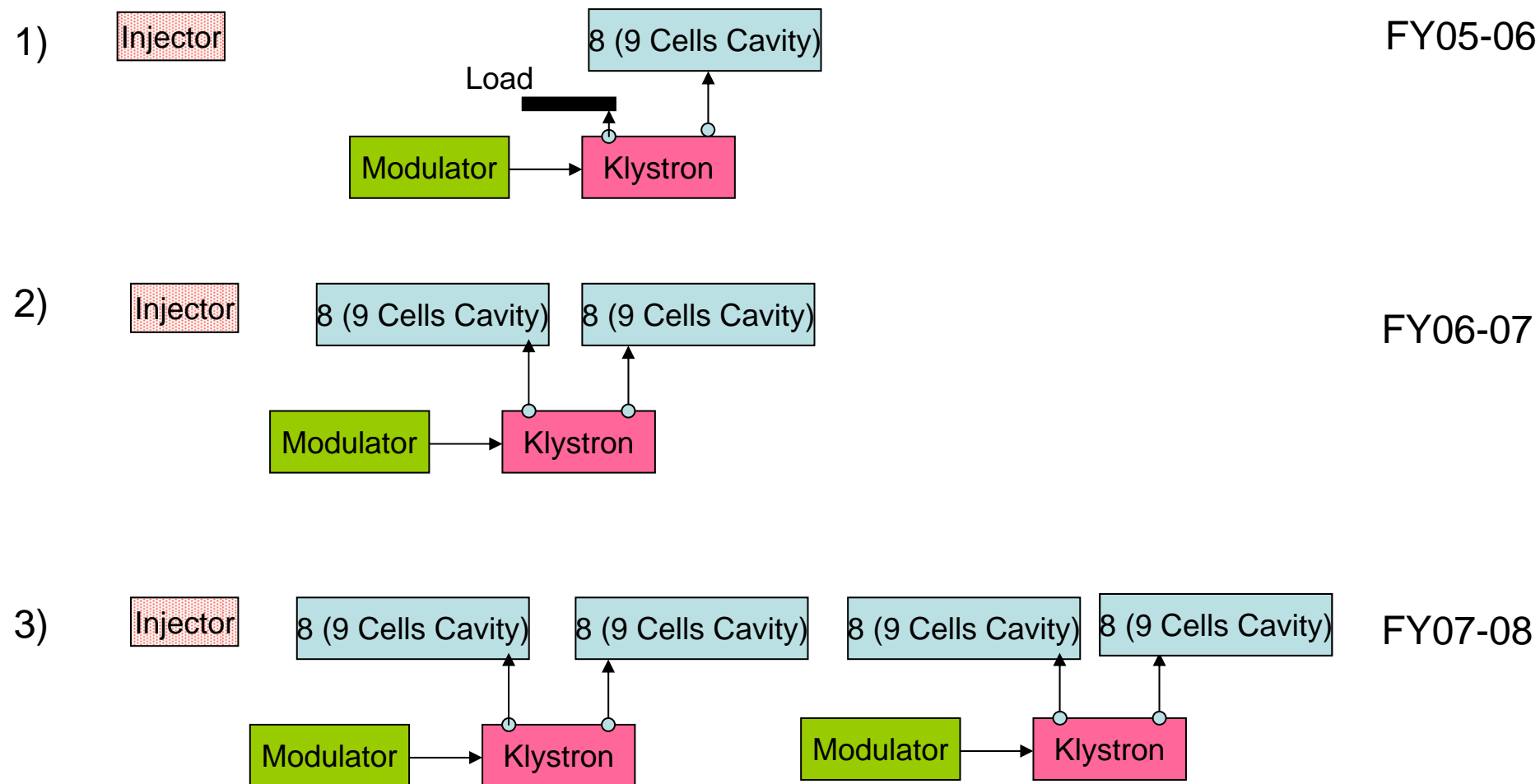
- **Phase 1:**
 - Installation of infrastructure, rf power etc to test a single ILC cryomodule within the high gradient pulsed test area.
 - This cryomodule is anticipated to be provided by TESLA Collaboration.
 - Relocation and re-commissioning of the Fermilab NICADD Photo-injector in the SMTF.
 - Initiate beam tests of a single ILC cryomodule utilizing the photo-injector.
 - Initiate construction of an ILC cryomodule
- **Phase 2:**
 - A complete ILC one rf unit consisting of two high performance cryomodules, fabricated by the ILC-America collaboration with industrial partners.
 - Install associated power
 - Operate this rf unit with beam
- **Phase 3:** Upgrade to two ILC RF unit: 4 Cryomodules, 2 High Power Klystron and Modulators.

We anticipate that development of the facility will be done in consultation with the ILC Global Design Initiative, regional group.

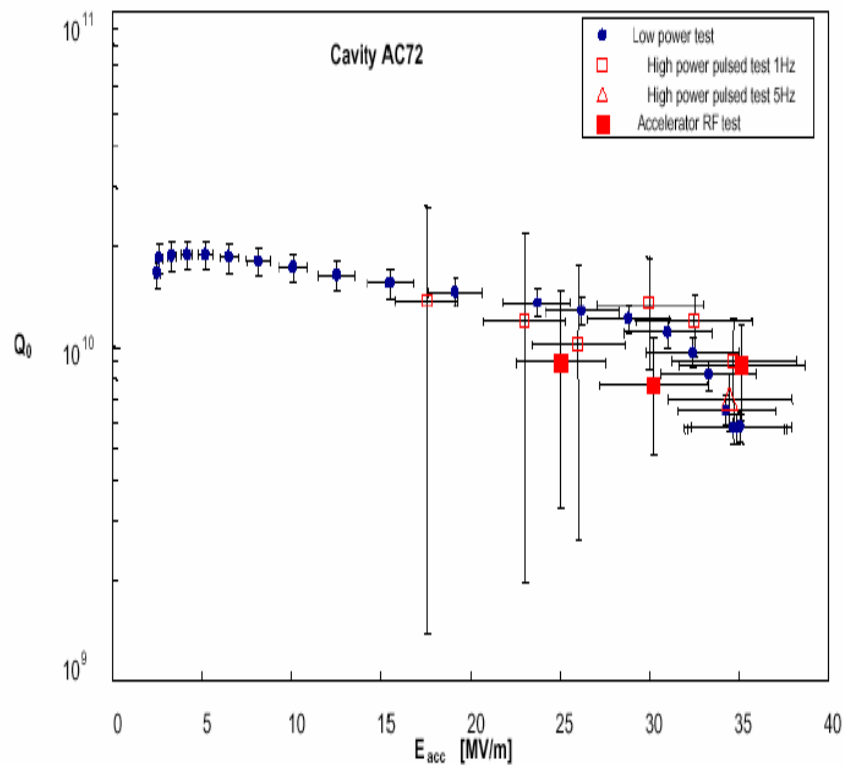


SMTF: Three Phase Approach

1.3 GHz Cryomodule Test Facility



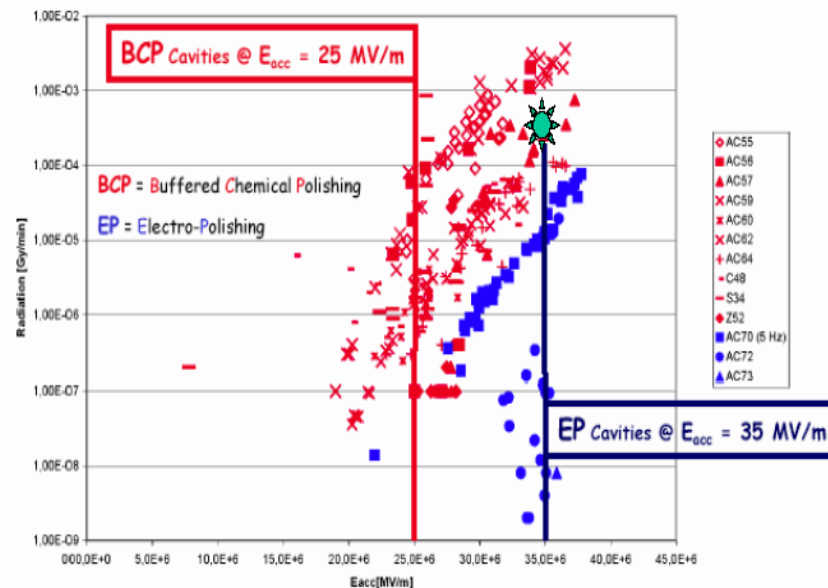
ILC Goals



> 35 MV/m and $Q \sim 10^{10}$

50 nA @ 35 MV/m per cavity acceptable ≈ 250 mW per cavity at 35 MV/m, estimated acceptable radiation dose

Radiation Dose from the fully equipped cavities while High Power Tested in "Chechia"
"Chechia" is the horizontal cryostat equivalent to 1/8 of a TTF Module



Low Dark Current

- Considerable amount of accelerator physics studies can be performed



Measurements and Tests

- Maximum operating gradient each cavity & its limitations.
- Dealing with spread in gradient limitations
- Dark current, cryogenic load, dark current propagation, wakes, radiation levels
- Quad, cavity, BPM alignment, thermal stability, vibration, cavity center HOM measurements
- Systems trip and recovery rates, life tests
- LLRF control and exceptions handling
- RF control and beam properties-energy, energy spread, variation, emittance control and test
- **Reliability Issues-Critical sub systems**
 - Failures with long recovery time: vacuum failure, Tuner failure, piezo failure, coupler failure
 - Components replacement using robotics



How to start SMTF : ILC

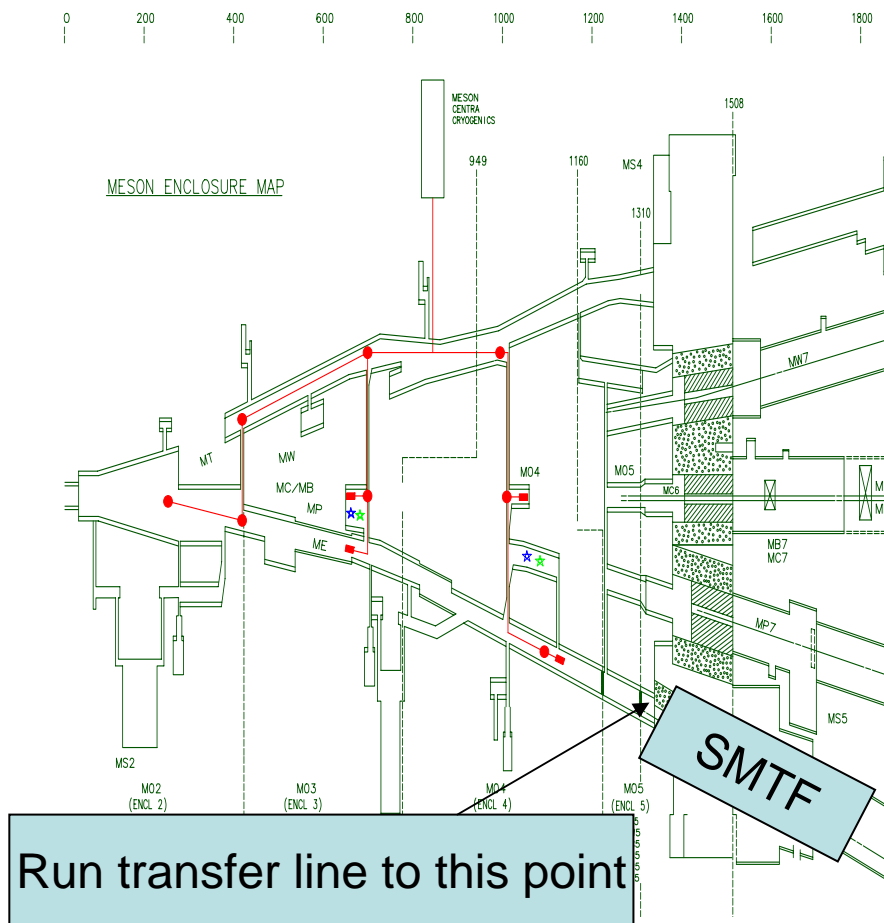
- Use Tesla Collaboration cryomodule to start
- **In parallel:** ILC-America needs to develop plan to
 - Develop capabilities to build >35 MeV/m cavities in US industry (Start with Tesla design)
 - Builds tuners, input & HOM couplers etc
 - Establish definition and pipeline for processing
 - Vertical & Horizontal Dewar tests
 - String assembly at US laboratories
 - Develop industrial partners
 - Construct cryomodules
 - Final Assembly of cavity and cryomodule
 - Testing at SMTF



Meson Area at Fermilab

Cryogenics Upgrade Plan

- Needs for phase 1→2b) is 60 Watts at 2K
- 80K liquid nitrogen, 4.5 K gaseous helium and 2.0K super fluid helium
- The cryogenic plant at Meson is capable of providing up to 60 Watts of 2 deg K He.
- In about 1 year the 60 Watt system can be operational.
- Phase 3 requires nx100 Watts refrigerator: Long lead time (2 years)





FNAL Meson Area SMTF Layout

Connection to
Meson Area
Cryo Plant

325 MHz
TESLA-Compatible
Beta <1 Linac Test

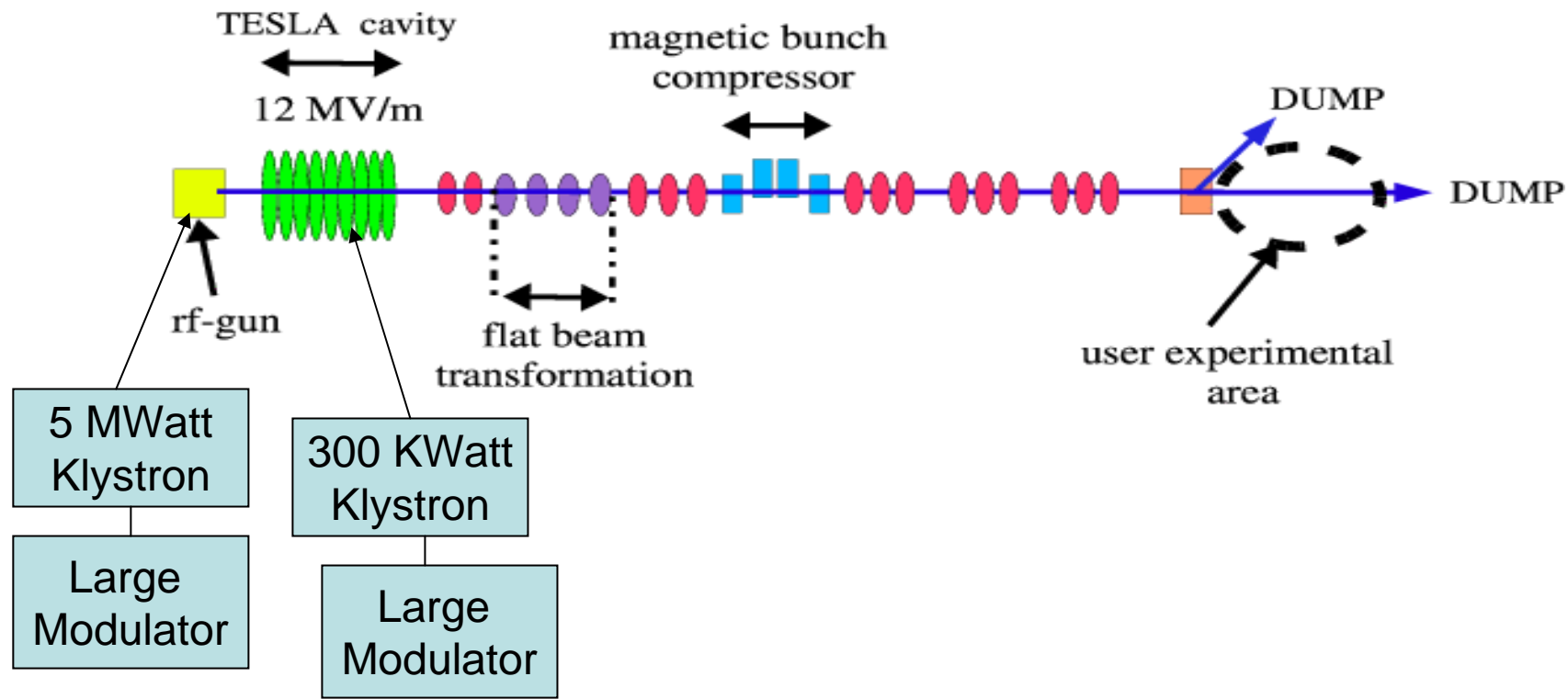
Four Cryomodule
System Test

CW Area

A0 Photoinjector
& Beam Tests

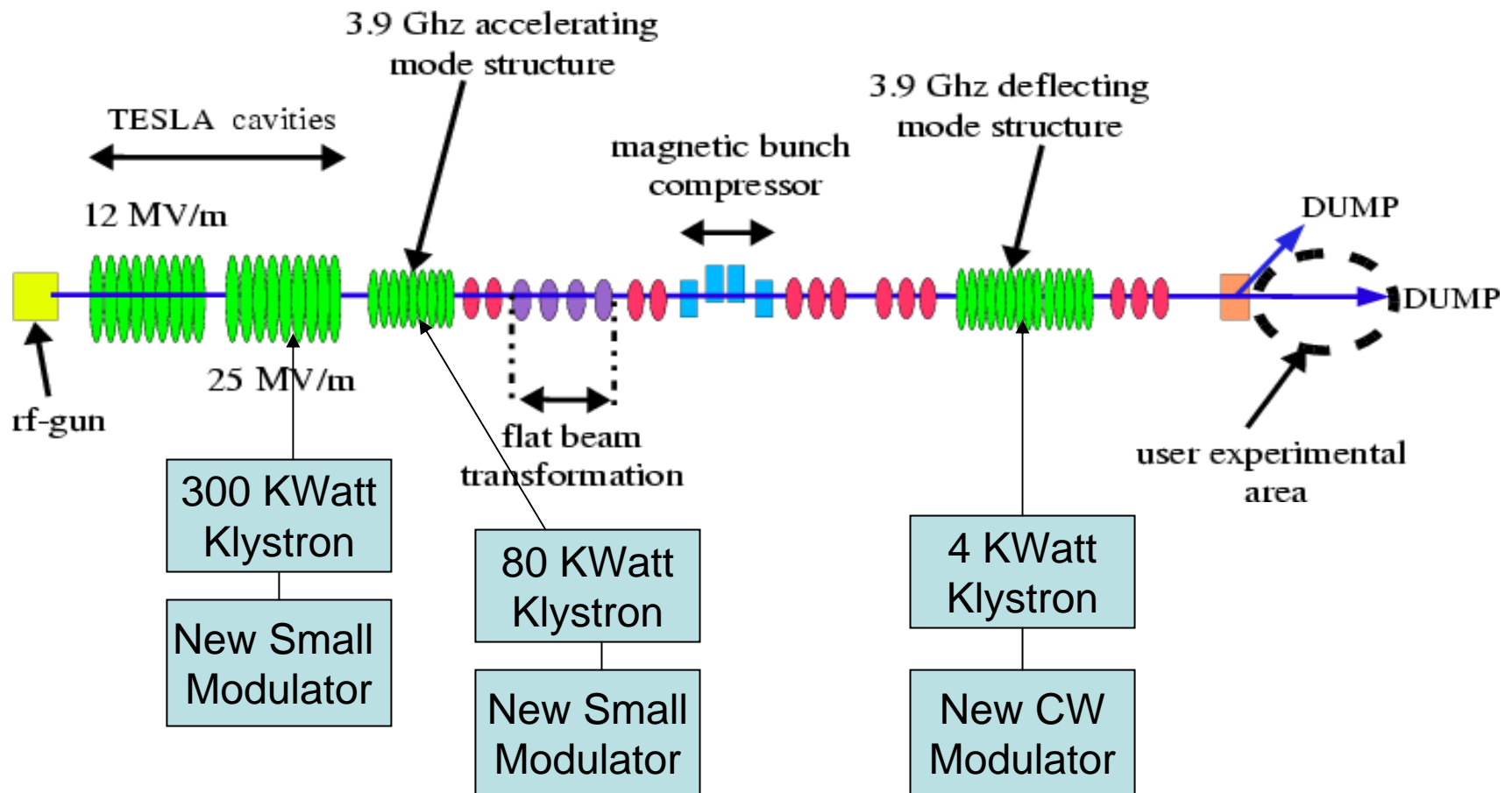


A0-FNPL Injector



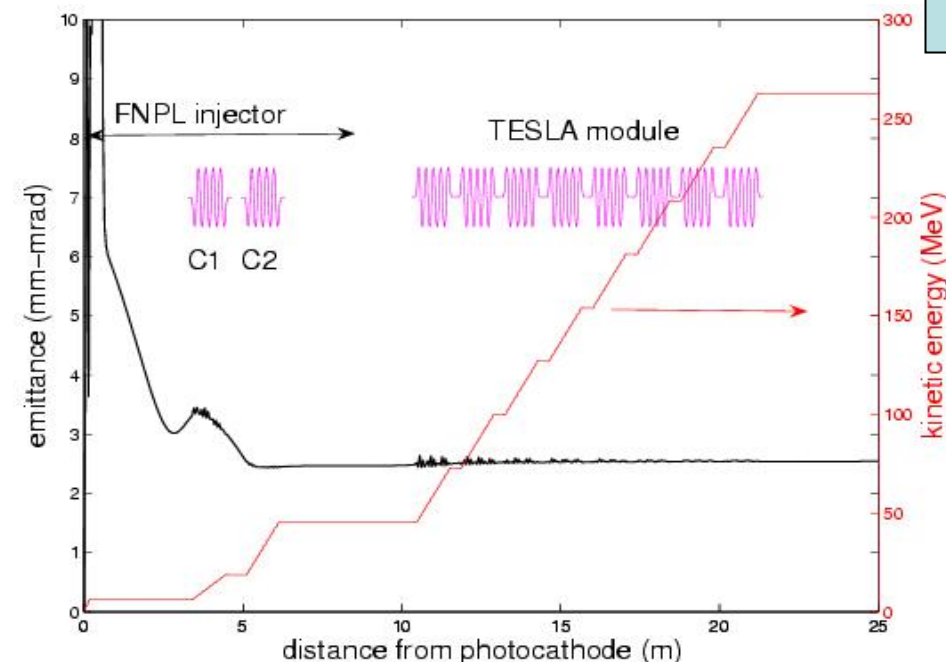
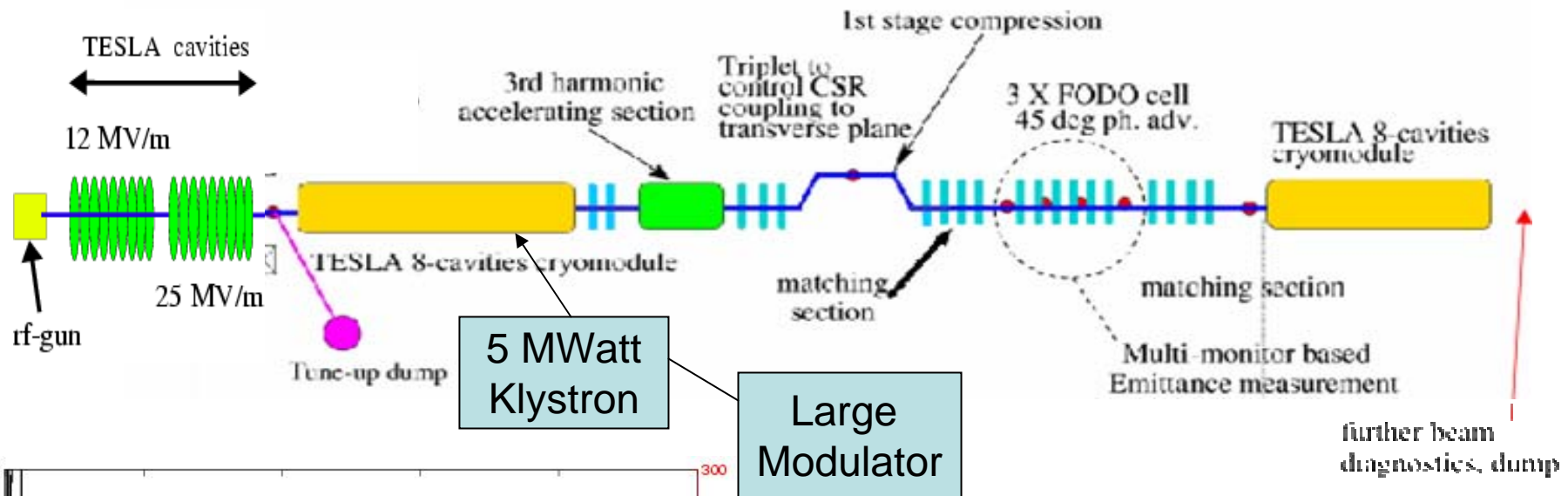


A0U-1st stage Upgrade of FNPL





A0U1-2nd Stage Upgrade of FNPL



Example of transverse emittance (black) and kinetic energy (red) evolution for a 3.2 nC bunch (TESLA nominal charge). C1 and C2 are the two TESLA cavities to be operated in the FNPL upgrade (here operated at 12.5 and 25 MV/m average accelerating gradient). The upgraded FNPL injector extend from $z=0$ to $z=8$ m. The beam is then injected in a TESLA accelerating module. The magenta curves stands for the longitudinal fields, i.e. the location of the TESLA cavities.



RF Power: ILC

- RF power with two different frequencies initially 1.3 GHz and 3.9 GHz.
- We plan to be able to accommodate two ILC RF unit (32 cavities) at the SMTF facility for ILC.
- Additional RF power will be needed for Horizontal test stand.
- Each RF unit is powered by one 10 MW klystron. 1.3 GHz klystrons would be purchased from one of the three vendors used by DESY
- Klystrons: 5 klystron types (5 MW Thales, 10MW MBK, 300 KW Phillips (all at 1.3 GHz), 80 KW 3.9 GHz CPI, 3.9 GHz 4 KW CW klystron CPI
- Fermilab designed modulator is adequate for test facility
- If we use 8-cavity cryomodule then need:
 - 3 large modulators High Power (5-10 MW)
 - 2 small 3.9 GHz modulators, Low Power (300-80KW)



DESY

DESY Actions if Technology Choice is COLD

- Actions will mostly be **specific to LINAC technology**
- Goals:
 - Participation in the implementation / construction of one or more **SRF Module Test Facilities** (wherever they are built) for testing LC-type prototype cryomodules
 - This facility should support the rapid transition from the TTF Cryomodule (CM) → LC CM
 - Participation in large scale industrialisation in all three world regions (in Europe this process was begun with the TESLA TDR, and its continuation is now funded through the EU FEL Design Study and the XFEL project)



DESY

Cryomodule Work

- **LC specific work:**
 - Work on high gradient programme continues, main emphasis will be on yield (= quality control), procedures are established
 - CM with $>35\text{MV/m}$ construction & test
 - design of LC CM (quad position, length etc.) will require additional efforts
 - Engineering only (not fundamental R&D)
 - can be ramped up quickly
 - connection with CARE SCRF Joint Research Activity



DESY

Other Actions

- TESLA collaboration can **supply TTF-like CM** with 35MV/m cavities with current infrastructure/manpower/expertise (some additional resources are needed)
 - in parallel / synergy with XFEL preparation
 - to be **shipped to new LC test facility**
- In parallel (ramped up), R&D (within GDI context) on LC CM design
- In parallel work on large scale industrialisation
 - with industry (XFEL will play an important role in Europe)
 - with collaborating labs (US collaboration and Japan)



DESY

TESLA Collaboration Role as part of the GDI

- TESLA collaboration/DESY role:
 - A large part of **XFEL preparatory work** & R&D is directly applicable (transferable) to LC
 - industrialisation
 - cavity production
 - Klystrons & RF distribution
 - LLRF, tuners etc.
 - cryoplants
 - reliability
 - ~30% TTF-II beam time available for LC work
Note: 100% of time will provide invaluable experience for a future cold LC, especially the ~40% stable operation of FEL users
- Will integrate interested LC collaborators in this process

- SLAC, Fermilab,... will participate in beam studies at TTF-II

KEK View



SMTF Meeting at JLab (Sep.30, 2004)
Nobu Toge, Accelerator Lab., KEK

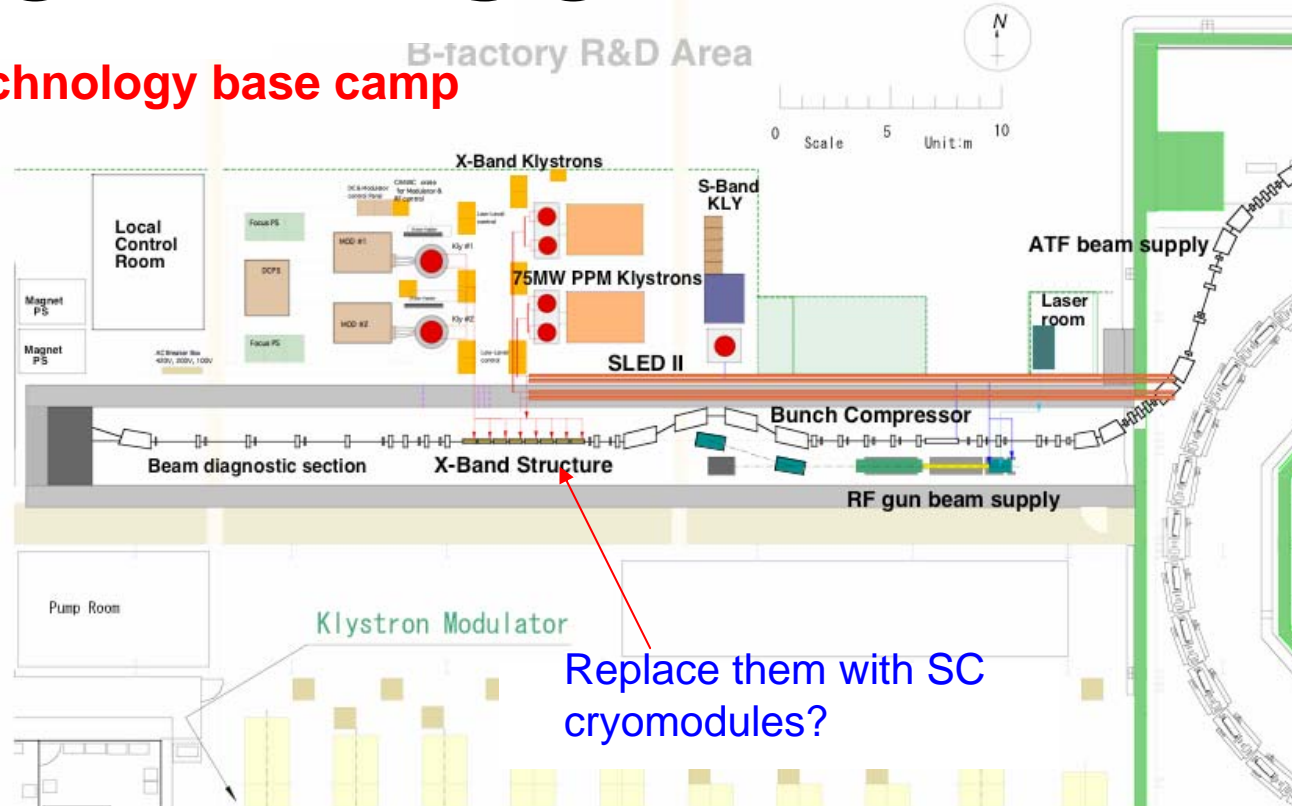
So what do we do technically?

Key areas are -

- Site studies in Japan will be continued.
- Studies of cold-oriented CF issues will be re-launched.
- Beam I&C studies at ATF will continue.
- Roles of ATF in conjunction with SRF-LC injector systems are being re-examined.
- SRF is an area where we would like to play big roles.
- X-band technologies are to be maintained with limited-scale activities separated from ILC.

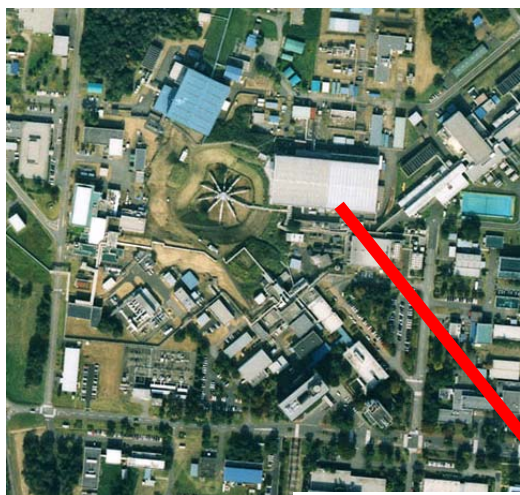
GLCTA → SCRFTA???

Technology base camp



- Note: Another site, “high-intensity proton linac” (for J-PARC) is considered more attractive by some influential members.
- There where-about of this “project” is still under discussion.

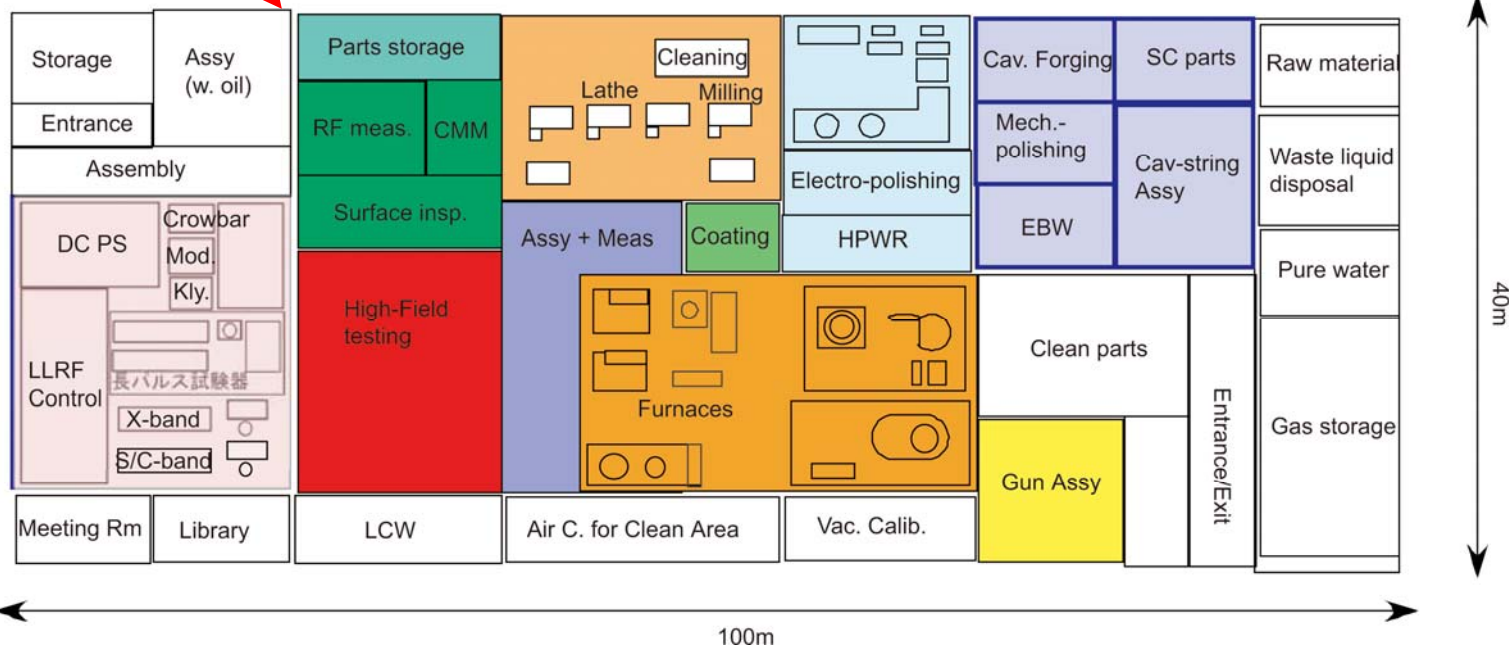
Proposal: New, Advanced RF Lab



Anoter Technology base camp

- This idea, which was presented at the time of ITRP-visit to KEK in May, still alive, because
- It is designed to support many aspects of SRF development, too.

Convert KEK's old proton synchrotron exp hall (or something similar in size) into this →



SRF

- Looks we would like to pursue the following two areas with initial emphasis on the former:
- 35MV/m issues (2005-2006):
 - 35MV/m-grade cavities in cryomodules.
 - Reliable production techniques for 35MV/m-grade cavities
- 45MV/m issues (2005-2007/8):
 - Demonstration of feasibility
 - 45MV/m-grade cavities in cryomodules.

35MV/m issues

- DESY/TESLA-style cavity design.
- Environmental / process controls of the production sequence with the industries.
- Production engineering studies for cost control.
- Would like to integrate these efforts with the ones in EU and NA.
- This perhaps should be our initial world focus.

45MV/m issues

- With the known $H(\text{rf})$ limit ~ 1750 Oe, with suitable (i.e. non-crazy) cavity shaping, $E_{\text{acc}} \sim 50\text{MV/m}$ appears to be within our reach.
- Hence, shoot for 45MV/m goal.
- Adequate cavity shape + careful surface treatment.
- Issues may remain with: reduced iris aperture \rightarrow HOM, increased $E_s \rightarrow$ MP, new coupler designs, etc.
- Basic pilot studies first, engineering details later.

Issues and Comments (1)

- On SRF, we seem able to consider a viable scenario for clearing the old “TESLA R1” and a step or two beyond it, within ~2 yrs.
 - i.e. 35MV/m-grade cryomodules
 - Establish reliable 35MV/m
- So we should just go ahead and do it.
- Industrial mass production of cavities needs attention.
- Engineering of cryomodules require much, much attention, too.